PB-230 282

PRELIMINARY RECOMMENDATIONS FOR INITIAL SURVEY PERIOD HUDSON-CHAMPLAIN AND METROPOLITAN COASTAL WATER POLLUTION CONTROL PROJECT

Hydroscience, Incorporated
Leonia, New Jersey

May 1965

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 230 282

U.S. Department of Health, Education and Welfare
Public Health Service
Metuchen, N.J.

PRELIMINARY RECOMMENDATIONS FOR INITIAL SURVEY PERIOD HUDSON-CHAMPLAIN AND METROPOLITAN COASTAL WATER POLLUTION CONTROL PROJECT

Hydroscience Inc.
Leonia, N.J.

May 1965

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

I
LIBRARY
Environ. Prot. Agency, WQO
Edison, New Jersey 08817

5

HYDROSCIENCE, INC.
Consultants in Water Pollution Control
316 BROAD AVENUE
LEONIA, NEW JERSEY
201 - WI 4-5550

W. WESLEY ECKENFELDER, JR.
DONALD J. O'CONNOR

EDWIN L. BARNHART
JOHN L. MANCINI

May 1965

Mr. Paul De Falco
Project Director
Hudson-Champlain and Metropolitan
Coastal Water Pollution Control Project
U.S. Public Health Service
Metuchen, N. J.

Dear Mr. De Falco:

In accordance with Purchase Order No. 50054-65, dated April 14, 1965, we are hereby submitting a report entitled "Preliminary Recommendations for Initial Survey Period of the Hudson-Champlain and Metropolitan Coastal Water Pollution Control Project." This report recommends immediate measures to be taken in the proposed comprehensive study of the metropolitan New York Harbor complex and adjacent areas. A general description of the study region is presented and component water bodies are defined and described. A preliminary classification scheme is outlined with specific reference to the project elements. The various component water bodies are listed together with qualitative assessments of those data immediately required for preliminary evaluation. General considerations concerning water quality surveys are indicated with particular reference to the area of investigation. Finally, conclusions and recommendations are presented regarding initial steps to be taken in the proposed study.

Respectfully submitted,

John P. St. John

JPS:ev

II

TABLE OF CONTENTS

INTRODUCTION	1
GENERAL DESCRIPTION OF STUDY AREA	3
PROPOSED PRELIMINARY CLASSIFICATION SYSTEM	6
PRELIMINARY CLASSIFICATION OF STUDY AREA COMPONENTS	11
GENERAL SAMPLING REQUIREMENTS	20
Sampling Programs	20
Water Quality Criteria	24
Related Measurements	29
SPECIFIC RECOMMENDATIONS FOR COMPREHENSIVE STUDY AREA	31
New York Harbor Complex	31
Hudson River Estuary	36
Upper Hudson and Mohawk Rivers	39
Lake Champlain	41
TABLES	
FIGURES	

LIST OF TABLES

1	NEW YORK CITY DEPARTMENT OF PUBLIC WORKS SAMPLING STATIONS
2	RECOMMENDED SAMPLING STATION LOCATIONS FOR THE UPPER HUDSON RIVER ESTUARY

LIST OF FIGURES

1	LOCATION MAP OF METROPOLITAN NEW YORK HARBOR COMPLEX
2	LOCATION MAP OF HUDSON RIVER, MOHAWK RIVER AND LAKE CHAMPLAIN
3	PROPOSED SAMPLING STATIONS FOR METROPOLITAN NEW YORK HARBOR COMPLEX

INTRODUCTION

The New York Harbor complex is located within the metropolitan area comprised of the most densely populated portions of New York, New Jersey and Connecticut This region is characterized by the most advanced industrial development on the east coast of the United States. The many waterways forming the metropolitan harbor system provide an effective means of municipal and industrial waste disposal due to the tidal nature of the area and the proximity of open ocean waters. However, indications exist that water quality in this region has been seriously depressed as a result of large discharges of both treated and untreated waste water. A program of appraisal and definition of present water quality in the system is therefore proposed. Mathematical simulation of the water bodies under consideration and analysis of collected data will permit a quantitative, integrated appraisal of presently existing conditions. In addition, water quality may be projected for anticipated future municipal and industrial waste discharges. The analysis will provide a framework for the development of a master comprehensive plan for the area under consideration. Such a plan will incorporate existing and projected water quality conditions in the determination of required waste treatment facilities and other methods of control for anticipated future loadings.

It is the purpose of this report to recommend immediate measures to be taken in the proposed comprehensive study of the metropolitan New York Harbor complex and adjacent areas. A general description of the study region is presented and component water bodies are defined and described. General considerations concerning any water quality survey are indicated with particular reference to required

data for the proposed study. Further, the various component water bodies are listed together with qualitative assessments of the data immediately required for preliminary evaluation. Finally, conclusions and recommendations are presented concerning initial steps to be taken in the proposed study.

GENERAL DESCRIPTION OF THE STUDY AREA

The New York Harbor complex and adjacent tributary areas are composed of a number of smaller water bodies, each defined by certain geophysical, hydrological and hydraulic characteristics. Changes in waste water discharge in any one of the elements not only affects water quality within the element, but also in contiguous components of the system. The comprehensive study area may be envisioned as a series of individual component water bodies, each of which affects, in varying degrees, its related members. The system is analyzed by considering the various components separately and then progressively integrating each into the larger plan. A general location map of the study area is presented as Figures 1 and 2.

The center of the system may be taken as the Upper New York Bay. This basin is connected to and surrounded by four major water systems, each of which affects Upper Bay water quality in some manner. The largest and most important of these as a fresh water source is the Hudson River, joining the Upper Bay at its northern extremity. Virtually all fresh water flow entering the New York Harbor complex, with the exception of sewage and industrial waste discharges, is supplied by the Hudson. The portion of the Hudson between the Battery and the Westchester County line will be termed as the North River in the present report. The second water course connecting to the Upper Bay at the northern limit is the East River, a tidal strait connecting the Bay and Long Island Sound. This body may be classified in two sections: the Lower East River from the Battery to the vicinity of Wards Island, and the Upper East River from Wards Island to Throgs Neck. At this latter location, the East River

joins Long Island Sound. Previous analyses have shown that no significant net flow exists in the East River. All water movement is tidally induced and purely oscillatory in nature. In the vicinity of Wards Island, the East River joins the Harlem River which, in turn, connects with the North River in the region of Spuyten Duyvil.

On the western extremity of Upper New York Bay, a confluence exists with Newark Bay by means of Kill Van Kull. The two major tributaries of Newark Bay are the Hackensack and Passaic Rivers draining the northeastern portion of New Jersey. From Newark Bay, the Arthur Kill runs to the south into Raritan Bay. The Raritan River is also tributary to the bay at this location. Along its course, the Rahway River, the Elizabeth River, and Fresh Kills drain into the Arthur Kill in addition to a number of smaller tributaries.

The Narrows connects the Upper Bay with Lower New York Bay. It is by this means that the harbor complex is most directly affected by the ocean. The westernmost portion of this basin encompasses Raritan Bay and the system may roughly be considered to border the ocean proper between Sandy Hook and Rockaway Point.

Regions relatively near the metropolitan area are undergoing rapid population and industrial expansion and are properly viewed in the proposed comprehensive study. That reach of the Hudson River between the Troy Lock near Albany and the northern extent of the North River receives a considerable amount of municipal and industrial discharge. The Hudson River below Troy may be broadly classified into two reaches, both tidal in nature. The Upper Hudson Estuary, extending from the Troy Lock downstream to Kingston, is essentially a freshwater tidal body.

The Lower Hudson Estuary, encompassing that reach from Kingston to the North River, is similarly tidal and is increasingly affected by salt water intrusion from the ocean.

Just as the New York Harbor complex must be regarded simultaneously with its components, the Hudson Estuary below Troy is properly viewed together with major tributary streams. Above Troy Lock, the Hudson River extends northward as a fresh water non-tidal stream to the headwaters located in the Adirondack Mountains. Along this course and just above Troy, the Hudson is joined by the Mohawk River, a non-tidal fresh water stream draining a considerable area of the central portion of New York State. In addition, the Hudson River upstream of the Mohawk confluence is joined by the Champlain Canal. This waterway provides ultimate access from the Hudson to Lake Champlain and the St. Lawrence. It is to be noted that the Hudson River above Troy receives flow discharges from a number of tributary streams, the most significant of which are the Schroon, Sacandaga, Batten Kill and Hoosic Rivers.

PROPOSED PRELIMINARY CLASSIFICATION SYSTEM

Each of the component water bodies indicated in the previous section display certain characteristics, often similar in some aspects. It is helpful to define such characteristics to reveal both similarities and differences among components of the system. This procedure will facilitate and simplify any comprehensive study as field survey procedures may also be classified as to the type of system to be observed. In general, the following characteristics will be used to define, in a preliminary manner, the various waterways of the comprehensive study area:

I. Nature of Component
   - A. Tidal Bodies
     1. saline
     2. non-saline
   - B. Non-Tidal Bodies
     1. fresh water streams
     2. lakes

II. Homogeneity
   - A. Completely Mixed (three dimensional homogeneity)
   - B. Partially Mixed
     1. two dimensional homogeneity
     2. one dimensional homogeneity
   - C. Unmixed (non-homogeneous)

III. Hydrology

A. Surface fresh water runoff

B. Ground water inflow

C. Direct rainfall, evaporation and transpiration

D. Artificial fresh water sources and sinks

IV. Geomorphology

A. Channels (constant or variable)

1. longitudinal area

2. longitudinal depth

B. Basins (lakes and embayments)

1. surface area

2. volume

3. depth

C. Oceanic nature

V. Waste Inputs (point sources and distributed load)

A. Continuous

B. Intermittent

The hydraulic nature of the component body, whether tidal or otherwise, is of particular importance in establishing the type of field survey to be conducted. In areas where significant tidal excursion may be anticipated, sampling procedures must consider the possibility of tidally produced variations. The same-slack survey technique may be adopted to account for tidal translation. Temporal

sampling may also be indicated. A different method of observation must be used if such a procedure is not practical. However, a determination of tidal effects must be included in some manner. In addition, the salinity of tidal waterways is pertinent as this factor may significantly affect dispersional patterns. Non-tidal bodies, such as lakes and fresh water streams, should be traversed rapidly, if possible, to illustrate instantaneous conditions. It is desirable to repeat such surveys to establish longer term variations. In any case, attention must be given to variations in fresh water flow and waste discharges for a period preceding the survey. It is most desirable to conduct surveys when variations are minimal and steady-state conditions are approached.

The homogeneity of a system, in part, determines the location and number of samples required to define water quality. A substantial saving of effort can be realized if this characteristic can be approximately evaluated. The ideal situation, from a practical standpoint, is the completely mixed system. Three dimensional homogeneity exists in this case. A relatively limited amount of field sampling may therefore be representative of conditions existing at the time of the survey. In addition, any resulting mathematical simulation is similarly simplified. Survey procedures become more complex with every decreasing degree of dimensional homogeneity. The most difficult of all systems to sample is the completely non-homogeneous type. This situation requires that extreme care be exercised during sampling to determine quality variations.

The hydrology of the system in the sense of water addition and removal is also a factor. Variations in fresh water input, known or anticipated,

are of significance to proper survey timing. This factor may be effectively eliminated from consideration in regions where fresh water discharge is known to be minimal or non-existent. Similarly, other sources of fresh water addition, such as ground water inflow and direct rainfall, will also affect the water balance of a system. In some cases, evaporation and transpiration must also be considered. These factors, however, are likely to be less significant that artificial fresh water sources and sinks. Proper interpretation of survey data can only be realized if accurate measurements are available on municipal and industrial flow requirements and releases. Further, the value of survey data increases if measurements are obtained at conditions approaching steady-state flow.

The geomorphology of the component is of special importance in the development of a comprehensive sampling program. A knowledge of size, shape and other factors, facilitates the development of a realistic hypothesis of the mechanics of assimilation within a specific area. Geomorphological characteristics will serve as a guide for anticipated investigations with regard to the type of sampling program to be conducted, the number and type of samples required, intensity and duration of the necessary measurements, as well as providing essential information for preliminary mathematical simulation. Very broadly, inland waterways may be classified as channel or basin shaped. It is recognized that any particular waterway may exhibit some qualities of both types. However, the body under consideration may be divided into components, each of which more nearly conforms to a particular classification. Each of the foregoing types displays certain characteristics of significance to the understanding of observed water quality. Longitudinal variations of area and

depth are common in watercourses of channel structure. Such changes may affect runoff velocities, dilution volume, and natural reaeration to a considerable extent. In contrast, water quality in bodies of basin structure is more likely to be affected by surface area, volume, and depth characteristics. The parameters are also pertinent to regions basically oceanic in nature.

Any comprehensive program of water quality evaluation should include the measurement of all known waste sources prior to and during survey periods. Observed water quality is of limited value unless related directly to waste inputs. It is recognized that these discharges are probably variable in nature, both on a flow and quality basis. Every attempt should be made to determine those waste characteristics which affect or have been responsible for water quality conditions observed at any particular time. In non-tidal bodies such as fresh water streams, exhibiting a channel structure, waste discharge measurements of a day or two preceding the quality survey proper may suffice. In tidal areas of basin structure, however, waste input measurements of a much longer period, perhaps a month, are desirable. Continual measurements of one type or another may be of pertinence in such cases. It is also of importance to determine the manner of waste discharge, whether a point, multiple point, or distributed load.

PRELIMINARY CLASSIFICATION OF STUDY AREA COMPONENTS

Each of the component water bodies previously outlined may be reviewed with regard to the proposed preliminary classification system. Such a procedure will serve as a guide for establishing initial survey and background requirements. The individual components of the comprehensive study area are therefore re-evaluated with reference to specific characteristics.

Upper New York Bay

The Upper Bay is a saline, completely tidal system exhibiting basin structure. Previous data collected in this region have indicated the likelihood that the area is basically a completely mixed system with respect to the concentration of waste material. This condition is due to mixing caused by tidal dispersion and to the location and number of wastewater outlets. The major source of fresh water addition to the bay is the Hudson River. Municipal and industrial discharges are probably substantial. The effects of ground water inflow, direct rainfall, evaporation and transpiration are likely to be minimal. A significant amount of background material is available for determination of the surface area, volume, and depth characteristics.

North River

This reach of the Hudson River is a saline tidal system of channel shape. Variations of water quality criteria are noted in the longitudinal and vertical dimensions. Any sampling conducted in this region should investigate the

extent and degree of vertical and lateral stratification. The largest portion of fresh water flow in the North River has its origin in the upper reaches. Ground water inflow, evaporation and transpiration are likely to be minimal. The cross-sectional area and depth within this reach are generally constant as revealed by published data. At present, raw sewage is discharged to this component from the west side of Manhattan Island continuously and as a distributed load.

Lower East River

The lower portion of the East River is a saline, tidal region of channel structure. This reach exhibits partial mixing and homogeneity in the vertical and lateral directions. Significant water quality variations are noted in the longitudinal dimension. As indicated previously, the East River is a strait with no significant net flow. Like the North River, the channel is well defined and is relatively constant in cross-section and depth. That portion of the Lower East River from the Battery to the Newtown Creek receives continuous raw sewage flow from Brooklyn, Queens and New York Counties entering as a distributed load. In addition, two point sources of considerable magnitude are Newtown Creek and the Wards Island sewage treatment plant discharge.

Upper East River

The Upper East River is a saline, tidal body of widening channel structure. Longitudinal variations in water quality have been observed as with the lower reach. In contrast, this area displays a pronounced increase in cross-section

toward Long Island Sound. Significant waste inputs in this region are the continuous point discharges from the Bowery Bay, Hunts Point, Tallmans Island, and New Rochelle sewage treatment plants.

Harlem River

The Harlem River is a saline, tidal body of channel structure. Available data shows pronounced variations in water quality through the tidal cycle indicating the presence of longitudinal gradients. Lateral and verticial homogeneity are presumed but must be verified. Little information is available on net flow through this component of the study area. Longitudinal cross-sectional area and depth appear to be uniform. Most of the area bordering the Harlem River is within the Wards Island sewerage district. However, a significant amount of raw sewage enters this watercourse from unintercepted lines running the entire course. It should be noted that all intercepted sewers circumscribing the harbor elements previously described are governed by flow regulator systems. When normal dry weather flow is increased to a certain level by storm water runoff, the regulators open and raw sewage and storm water are discharged to the proximate watercourse. The immediate effects of such discharge are not well defined at present but should be investigated.

Kill Van Kull and Arthur Kill

Kill Van Kull and Arthur Kill are saline, tidal straits of channel structure similar in nature to the East River. Lateral and verticial homogeneity should be verified during field study. Past data have indicated that significant longitudinal variations exist with regard to water quality. In addition to municipal

and industrial discharges, the most significant source of fresh water flow is the Rahway River. Longitudinal area and depth variations require evaluation. The Kills are surrounded by areas of extensive industrial development. A large portion of waste discharged to these waters is presumably industrial in origin. During sampling of these areas, efforts should be made to determine the quality and quantity of such discharges. In addition, raw domestic sewage is contributed by the western portion of Staten Island, entering the system basically as a distributed load. These discharges, however, are not significant by contrast to the waste waters discharged from the Jersey shore.

Newark Bay, Passaic River and Hackensack River

Newark Bay is a saline, tidal body of basin structure while its major tributaries, the Passaic and Hackensack Rivers, are more complex components of channel shape. The lower regions of these two watercourses are known to be saline and tidal at least to the municipalities after which they are named. Above these locations, the rivers exhibit the characteristic transition from tidal to fresh water streams. Due to a lack of sufficient data, little is known as to the degree of mixing prevalent in the foregoing elements. Any sampling program should investigate this factor on an immediate basis. The major portion of fresh water flow entering Newark Bay is discharged from the Passaic and Hackensack, both of which are gaged at Little Falls and New Milford, N. J., respectively. It is to be noted that these streams are used for public water supply and many reservoirs and diversions exist within each basin. The surface area, volume and

depth of Newark Bay are primarily affected by the ocean level and tides. Longitudinal area and depth variations should be evaluated in the Passaic and Hackensack Rivers. Waste inputs to this system are not clearly defined but it is expected that from the nature of the surrounding area, a sizeable number of continuous point sources probably exist.

Lower New York Bay

The Lower Bay is saline, tidal, and essentially oceanic in nature. Water quality in this region from a physical and chemical standpoint is predominately influenced by ocean conditions. The importance of this area, however, is not to be minimized as conditions in this region are likely to exert an effect on those elsewhere in the metropolitan complex. The Lower Bay not only acts as a sink for waste discharges throughout the harbor area, but also as a source of high quality water. From a bacteriological standpoint, the Lower Bay is known to be severely affected by the many domestic discharges influencing its character.

Hudson Estuary

That reach of the Hudson River between Troy and the New York City line, known as the Hudson Estuary, may be divided broadly into two areas. The Upper Hudson Estuary, from Troy to Kingston, is a non-saline tidal body of channel structure. Flow reversals are noted to Albany. Past data have indicated this reach to be completely homogeneous in the vertical and lateral dimension. Pronounced longitudinal water quality gradients are observed. The greatest

portion of fresh water flow present is discharged over the dam at Troy Lock, at which a gaging station is located. Artificial fresh water sources and sinks are generally minor. The channel is characterized by a rapidly increasing cross-sectional area of linear function. Water depths are generally constant for substantial distances. The major waste discharges in this component originate in the Capital District area. Most domestic and industrial wastes receive little or no treatment. These discharges, over one hundred in number, enter the estuary as a series of continuous point sources. Many of the outfalls are closely spaced so that a portion of the discharges may be considered as a distributed loading

The Lower Hudson Estuary, from Kingston to New York, is a saline tidal channel. Vertical and lateral homogeneity should be evaluated. The major fresh water source is that of the upper estuary with a drainage area increase of approximately 10% from Troy Lock downstream. Artificial fresh water sources and sinks are probably minimal at present. Power development in this area is contemplated and may result in severe diurnal variations in water movement throughout the tidal cycle. Longitudinal area-depth-distance relationships require definition. The largest portion of waste discharge to this component is concentrated as a series of continuous point sources in the Westchester County area. It may be advisable to subdivide the lower estuary for any mathematical simulation on the basis of waste input location.

Upper Hudson River

The Upper Hudson River is a non-tidal fresh water stream from

the headwaters in the Adirondack Forest Preserve to Troy Lock. Very limited information is available on homogeneity and vertical and lateral variations, if any, must be defined. Longitudinal water quality gradients have been observed. Fresh water discharge is supplied by surface runoff and ground water inflow from the drainage basin. As noted, major tributaries are the Schroon, Sacandaga, Batten Kill and Hoosick Rivers, all of which are gaged. Almost one half of the Upper Hudson basin is drained by these streams. Area and depth relationships are not well defined at present and must be evaluated. The upper half of this river traverses virgin timberland and receives no major waste discharges at present from a physical and chemical standpoint. Localized bacteriological pollution is observed in some populated areas. Below the Schroon River, however, municipal discharges increase in size and frequency with a resultant decrease in overall water quality to the Troy Lock. The severest conditions are encountered in the Fort Edward area near the Champlain Canal entrance.

Mohawk River

The Mohawk River is a non-tidal fresh water stream from headwaters to confluence with the Upper Hudson River near Troy. This stream drains the central portion of New York State and passes several urbanized areas. Longitudinal variations in water quality have been observed. Fresh water is contributed by surface runoff and ground water inflow. The most significant tributary in the Mohawk Valley is West Canada Creek joining the mainstream near Herkimer. A number of gaging stations are maintained throughout the area. Cross-sections and depths

along the course of the river must be defined. Domestic wastes are discharged continuously along the entire course of the stream Significant waste sources are the municipalities of Rome, Utica, Amsterdam and Schenectady.

Lake Champlain and the Champlain Canal

The Champlain Canal is a non-tidal fresh water channel from confluence with the Hudson River near Fort Edward to the point at which it is tributary to Lake Champlain in the vicinity of Whitehall. That reach of the Hudson between Fort Edward and Waterford is actually part of the Champlain Canal system. The canal is approximately 60 miles in length and consists of 11 lockages including the Hudson reach. The summit level of the canal is located just north of confluence with the Hudson River. From this point, flow is directed south into the Hudson and north toward Lake Champlain. The source of water supply for the summit level is a feeder system which diverts a portion of the Hudson River above Glens Falls. Information regarding vertical and lateral homogeneity in the Champlain Canal is not available and must be defined. Cross-sectional areas in the artificial canal from Fort Edward to Whitehall are known but any localized variations should be determined. Longitudinal water quality changes have been observed but further definition is required. Net flow in the canal in both directions must be evaluated as part of any sampling program. Water quality in the feeder system should be measured during sampling operations along with other potential waste sources.

Lake Champlain is a fresh water non-tidal watercourse bordered by the states of New York and Vermont and extending to the Canadian boundary. The lake comprises over one hundred miles of navigable waterway and is used for municipal and industrial water supply and recreation. Little or no information is available on the homogeneity of this component. Stratification may exist in the area and must be defined. Lake Champlain is highly irregular in shape and longitudinal cross-sectional area relationships should be evaluated. The surface area of the lake has been determined as 435 square miles but volume and mean depth require definition. Water quality in Lake Champlain has been observed to be generally satisfactory by present standards. However, numerous waste discharges are known to exist and must be further investigated.

Of the foregoing components, within the comprehensive study region, knowledge of waster water inputs, system geomorphology and hydrology are fairly well defined in the following areas: East River, North River, Upper New York Bay, Upper Hudson Estuary. Preliminary mathematical models and analysis for water quality distributions have been established in each of these components. Sampling recommendations are based on these analyses and involve confirmation of existent loadings. In the remaining areas, existing data is either lacking or incomplete and should be reviewed in conjunction with the preliminary surveys proposed for this year.

GENERAL SAMPLING REQUIREMENTS

Certain general considerations are applicable to all types of water quality investigations, regardless of location. Particular regions or components of a system may exhibit special characteristics which require study and analysis of a more refined nature. Prior to the development of a comprehensive sampling program, qualitative judgements may be made on the basis of available information as to data requirements and survey procedures. It is the purpose of this section to briefly review types of sampling programs and water quality criteria leading to the advancement of specific recommendations.

Sampling Programs

Three types of sampling techniques are pertinent to the comprehensive study: spatial, short-term intensive temporal, and long-term temporal programs. These procedures may be employed singly or in conjunction as necessary. The first type refers to short term sampling in the space dimensions while the latter two are concerned primarily with time as the independent variable. The temporal types of survey may be used to reproduce spatial data depending on scope and duration. Each technique has specific value and may be used to advantage depending on conditions likely to be encountered.

The predominant purpose of the spatial survey is the definition of water quality concentration profiles as a function of distance. Data collected in this manner is particularly useful in the broad determination, at any given time,

of the spectrum of water quality in an area of concern. Critical regions are ascertained rapidly and the data collected will serve as a basis for more refined techniques, if necessary. Spatial survey data can also be used in the formulation of a mathematical model for the component or system under study. The data may then be reviewed quantitatively and related to the causes, natural and artificial, of water quality variation. Spatial surveys are usually conducted on a short-term intensive basis. The nature of the system studied is of importance in this regard. In areas such as fresh water streams where the environment responds quickly to waste inputs, it is desirable to plan the survey so that it may be completed within two or three hours. In estuarine or large basin structured components where quality response is somewhat slower, data collection may proceed for a longer duration, even two or three days if conditions are acceptable.

Spatial surveys conducted in estuarine systems provide more readily appraised data when the effects of tidal translation on water quality variations are considered during the survey period If concentration gradients exist in an estuarine component, water quality fluctuations will be observed at any location as the longitudinal distribution is spatially translated by tidal motion. The same-slack sampling technique considers such a factor. This procedure requires that every location in the component waterbody be sampled at the same point in the tidal cycle. The cycle of significance in this regard is tidal current velocity. An easily recognizable point of the tidal cycle is at slack water when the tidal current velocity is substantially zero. At this time for each location,

the least translation of the water mass occurs. A series of spatial samples collected during slack water conditions will yield longitudinal water quality distributions which are undistorted by tidal motion. It is recommended that estuarine waterways be sampled employing this technique where tidal conditions permit.

Systems are often encountered, however, where slack water conditions occur almost simultaneously over a wide reach or area. It may be impractical to employ the same-slack sampling technique. In such circumstances, a different type of sampling program is necessitated. Locations established to define spatial distributions may be sampled over a longer period of time at different points in the tidal cycle. The results may then be averaged to approximate mean tidal conditions. It is advisable to collect at least four samples at each location covering the entire range of tidal conditions. The times of sample recovery which might be selected are slack before ebb, maximum ebb current, slack before flood and maximum flood current. A single survey launch traversing a prescribed sampling pattern, beginning at the same time of day, and operating for a constant duration could approximate these or equivalent conditions at many locations. Tidal conditions at a specific point require approximately one week to reverse in the comprehensive study area. Consequently, such an investigation would take four days of sampling during a period of ten days. In this time, many conditions in the estuarine environment may change. Such data will not be as reliable as that collected by the same-slack technique in addition to requiring considerably more time to obtain.

Short-term intensive temporal sampling programs may be used to good advantage when performed in conjunction with spatial surveys. The purpose of this technique is to define water quality variations in the time domain at a specific location. This procedure is particularly valuable in assessing the magnitude of quality fluctuations produced by causal influences of short period. In non-tidal bodies such as fresh water streams and lakes, temporal sampling may be used to reveal the presence and quantitative effects of algal populations. Procedures are in development to quantitatively utilize such data for precise definition of algal production and respiration in the water environment. Information provided by proper short term sampling is essential to the understanding and control of this potential nuisance. Further, other benefits such as the response of the water body to changes in the natural or artificial environment are realized. In estuarine systems, quality variations produced by tidal movements may also be assessed. Statistical procedures are available to define the relative effects of all factors which cause water quality variations at a particular location. These methods pose certain criteria which should be considered in the establishment of short-term temporal sampling programs. Considering a situation wherein local quality variations are produced by tidal translation and algal production-respiration, the recommended sampling frequency is in the order of one or two hours. The results of the statistical analysis of such data are helpful in the development of mathematical simulation for the study area.

Long-term temporal sampling programs are valuable for observation of weekly or seasonal changes in water quality conditions. Further, in

selected regions of pre-determined especial significance, variations in quality may be related to causal influences of long period. Such factors may include annual variations in fresh water discharge and temperature, seasonal fluctuations in specific waste discharges, and long term changes in other parameters affecting water quality. Long term surveillance also provides a continuing check on quality conditions so that critical periods may be anticipated and the necessary controls initiated. Temporal surveys, short and long term, may be accomplished with automatic monitoring devices. However, certain parameters which may be pertinent to such investigations are not conveniently monitored at present.

Water Quality Criteria

Two of the more important indicators of water quality are dissolved oxygen concentration and the density of coliform organisms. Of the two, the dissolved oxygen balance of a waterbody is influenced by more parameters than is the coliform disiribution. Certain chemical and physical measurements must be performed conjunctively for precise definition of the demand on oxygen resources. Any water quality sampling program will require the determination of some or all of the following parameters.

1 Dissolved oxygen - mathematical simulation of the system will attempt to define this quantity after considering all oxygen demands and resources.

2 Biochemical Oxygen Demand - the standard 5-day value may be determined by conventional incubation or the Warburg method. On samples from selected locations, the Warburg apparatus may be used for long term oxygen uptake determinations. The information provided by such a procedure is essential to the proper interpretation of 5-day BOD values. Stream deoxygenation rates may also be evaluated by respirometer techniques. Long term studies by standard incubation procedures or Warburg should include provisions for the inhibition of the nitrification stage. The relative effects of the carbonaceous and nitrogenous fractions of organic pollutants may therefore be assessed.

3. Chemical Oxygen Demand - tests may be used as a rapid indicator of the total carbonaceous oxygen requirement of a sample. Such data is also useful in areas where biological toxicity may be a factor. If reliable relationships can be established between BOD and COD in a particular area or waste stream, chemical oxygen demands may be run as a routine with a limited number of control BOD's.

4. Total Organic Carbon - may be of significant value for analysis of samples where interferences lend other methods of carbonaceous determination to be unreliable. The relationship of total organic carbon, BOD and COD should be investigated

5. Chlorides - provide information on vertical and lateral homogeneity and the oxygen saturation value. Further, chloride distributions in estuarine components may be used for quantitative evaluation of the dispersion process.

6. Temperature - measurements are made to determine degrees of stratification and the variation, both spatially and temporally, of dissolved oxygen saturation values.

7 Suspended and Volatile Suspended Solids - will provide information on the manner of BOD removal in a component in addition to being primary data. Interpretation of the results may reveal that organic material is removed from stream waters by sedimentation as well as oxidation. Conversely, bottom material may also be scoured to overlying waters during periods of high flow.

8. Total Organic Nitrogen - provides an index of the amount of nitrogenous organic matter present in a sample. This parameter provides important information on the total

oxidation of organic material. The demands exerted by the nitrogenous fraction of such elements on the oxygen resources of a system may be significant.

9. Ammonia Nitrogen - presence is indicative of actual or incipient nitrification and provides information on the progress of total organic oxidation. The concentration of ammonia may be an important factor in the utilization of dissolved oxygen. Nitrogen in ammonia form may also be utilized by the microscopic plants for cell growth.

10. Nitrite Nitrogen - results as an intermediate phase in the total oxidation of nitrogenous compounds. Its presence is an indication that the second stage of the BOD progression has commenced. As nitrite nitrogen concentrations are generally small, this compound is not regarded as an important nutrient source for the microscopic plants and is the least important of the nitrogens to measure.

11 Nitrate Nitrogen - represents the most highly oxidized compound in the nitrogen cycle. Its presence in a sample reveals the degree of the total oxidation pro-

cess when viewed in relation to the other nitrogen compounds. Nitrate is an important nutrient for algal development and synthesis.

12. Total Phosphate - is another indicator of nutrient material available to the phytoplankton. Measurement of this compound should be made as a matter of course in areas of suspect algal activity.

13. Chlorophyll Extractables - provide a quantitative measure of the green aquatic plants present in a sample. Such data are particularly useful in tracing the development and growth of algae over a period of time. Longitudinal concentration profiles are helpful in assessing the relative density of the plants along the course of a waterway Such information is desirable prior to the mathematical simulation of the component.

14. Benthal Demands - may impose a considerable load on the oxygen resources of a system. Such demands may be caused by the deposition and accumulation of raw or poorly settled waste material. Oxygen uptake determinations from bottom deposits are more meaningful if accomplished in the field on undisturbed portions

of the river bed Alternately, bottom samples may be taken by dredge or coring device and returned to the laboratory for oxygen uptake measurements and other data.

15 pH - measurements should be taken routinely prior to all types of BOD determinations.

16. Bacteriological Examinations - should proceed routinely in all areas affected by domestic waste discharges Special studies should be conducted during periods of storm overflow.

Related Measurements

The following measurements are necessary to complete field investigations.

1 Fresh Water Discharge - should be measured as part of any water quality investigation in those areas not routinely gaged by the U.S. Geological Survey. Statistical analyses have been performed on New York State waterways within the comprehensive study area. Similar analyses should be conducted on the appropriate New Jersey streams

2. Domestic, Storm Water and Industrial Discharges - should be measured prior to and during the survey period unless sufficient information is available on the probable quantity Complete evaluation of treatment plant effluents including carbonaceous, nitrogenous and solids components are required. Sampling in combined sewers for both quality and quantity should be conducted before, during and after storm periods. Measurement of specific characteristics in industrial process waters should be accomplished in addition to standard analysis, as necessary.

3. Bottom Deposits exerting any appreciable benthal demand should be charted for the area of influence. Both extent and depth of the deposits should be evaluated particularly in the region of combined sewer and treatment plant overflows.

4. Dye Investigations - such studies will provide time of passage data in areas of highly irregular cross section or other complicating feature. Further, the data can be employed in the quantitative evaluation of tidal dispersion in non-saline regions where other indicators of the process are unavailable.

SPECIFIC RECOMMENDATIONS FOR COMPREHENSIVE STUDY AREA

The comprehensive study area may be conveniently divided into four regions for sampling purposes: the New York Harbor Complex, the Hudson River Estuary, the Upper Hudson and Mohawk Rivers, and Lake Champlain. Based on the foregoing considerations, a general sampling program will be described regarding each of the four regions. Specific measurements, supplemental to the general program, will be recommended as required. The following suggestions relate to moderate scale sampling of the water environment. It is expected that during the course of investigation, localized conditions may warrant sampling at a reduced scale. However, the emphasis placed herein will be to define water quality in sufficient detail to facilitate mathematical simulation.

New York Harbor Complex

A. Same-Slack Spatial Program

1. Measurements at every sampling location at mid-depth:
    a. Dissolved oxygen
    b. Biochemical oxygen demand (5-day)
    c. Temperature
    d. Chloride
    e. Bacteriological examination
    f. pH

2. Measurements at alternate sampling locations at mid-depth:

   a. Ammonia nitrogen

   b. Nitrite nitrogen

   c. Nitrate nitrogen

   d. Total organic nitrogen

   e. Suspended solids

   f. Volatile suspended solids

   g. Chemical oxygen demand

   h. Benthal demand (this examination may be conducted without regard to slack conditions and at or from samples collected on the channel bottom. In particular, bottom demand in the Upper and Lower East River should be investigated.)

3. Measurements at two sampling stations within each component of the complex:

   a. Total phosphate

   b. Total carbon

   c. Warburg respirometer determinations (including suppression of nitrification).

4. Lateral homogeneity should be investigated at all channel sampling locations throughout the New York Harbor complex regarding those criteria designated for measurement at each station. Bacteriological examinations may be omitted. A minimum of three equidistant mid-depth lateral locations is recommended. Such sampling may be conducted independently from the same-slack program on a preliminary

basis. Those channels, however, which are characterized by lateral variations should be comprehensively sampled during the regular program.

5. Vertical stratification is known to exist in the North River and Upper New York Bay. At least three depth samples, including the mid-depth and preferably more, are recommended at all survey stations located within the various components for criteria, exclusive of bacteriological examinations, to be measured at each station. This procedure should be followed as part of the regular same-slack sampling program. The possibility of vertical stratification in Newark Bay and the Hackensack and Passaic Rivers should be investigated on a preliminary basis.

6. It is recommended that the network of sampling stations adopted by the New York City Department of Public Works for the metropolitan complex be retained. A schematic diagram is presented as Figure 3 and the locations are listed in Table 1. Generally, these stations permit sufficient definition of water quality distributions for mathematical simulation and analysis. In addition, however, it is suggested that the following sampling locations be established for the comprehensive study as indicated on Figure 3:

Upper New York Bay

a. A station between N-6 and the western shore of Brooklyn

b. A station between N-7 and the western shore of Brooklyn

Kill Van Kull

c. A station between K-1 and K-2

Arthur Kill

d. Two stations between K-3 and K-4

e. Two stations between K-4 and K-5

Newark Bay

f. Four stations established as a grid system, each representative of a quarter of the bay area on a preliminary basis.

Passaic and Hackensack Rivers

g. A series of stations commencing at the confluences with Newark Bay and continuing upstream at two mile intervals to the headwaters.

Lower New York Bay

h. Two stations in Ambrose Channel between N-8 and a line connecting Rockaway Point and Sandy Hook.

It is to be noted that the sampling locations indicated for Jamaica Bay are generally sufficient to define overall water quality. This region, however, may be considered as a separate entity from the balance of the metropolitan complex. It is recommended that the bay be sampled in accordance with the same-slack technique, though not necessarily simultaneously with other components of the system

7. Based on previous analysis of available survey data, certain components of the metropolitan complex should be surveyed concurrently. It is suggested that the following component groupings be sampled simultaneously during a single same-slack survey:

   a. Upper New York Bay - North River - Harlem River

   b. Upper East River - Lower East River

   c. Arthur Kill - Kill Van Kull - Newark Bay

   d. Balance of the metropolitan complex

8. It is recommended that five same-slack spatial surveys be conducted on the New York Harbor complex during the forthcoming summer and fall, one each during the months June through October. Each survey should cover both slack before flood and slack before ebb tidal conditions, if possible.

B. Long-Term Temporal Program

1. Measurement at each sampling location

   a. Dissolved oxygen

   b. Temperature

   c. Chloride (conductivity)

   d. Current velocity and direction

2. The following sampling locations are recommended for continuous monitoring:

   a. North River near George Washington Bridge (sampling at three depths)

b. East River near Triboro Bridge (sampling at mid-depth)

c. Upper New York Bay at a representative location (sampling at three depths)

3. Samples should be monitored at each location on one or two hour intervals.

4. It is suggested that as much continuous BOD and COD data be collected as practical.

Hudson River Estuary

A Spatial Sampling Program

1. Measurements at each sampling location at mid-channel and depth:

a. Dissolved oxygen

b. Biochemical oxygen demand (5-day)

c. Temperature

d. Chloride (Lower Hudson Estuary only)

e. Bacteriological examination

f. Ammonia nitrogen

g. Nitrite nitrogen

h. Nitrate nitrogen

i. Total organic nitrogen

j. Suspended solids

k. Volatile suspended solids

l. pH

2. Measurements at every fifth sampling location at mid-channel and depth:

   a. Chemical oxygen demand

   b. Benthal demand (this examination should be conducted at alternate stations within the 20 mile reach between Troy Lock and New Baltimore)

   c. Total phosphate

   d. Total carbon

   e. Warburg respirometer determinations (including suppression of nitrification)

3. A series of sampling stations has recently been established in the Upper Hudson Estuary within the 50 mile reach between Troy Lock and Saugerties. Data collected from these locations sufficiently define water quality variations. It is recommended that these stations be adopted for use in the comprehensive program. Sampling station locations are indicated in Table 2. Below Saugerties, it is suggested that stations be established at 5 mile intervals to the North River. In the Lower Hudson Estuary, some preliminary investigations on vertical and lateral homogeneity are advised in addition to confirmation in the upper reach.

4. It is recommended that three to five same-slack spatial surveys be conducted on the Hudson River Estuary during the June through October period. Sampling should be conducted at both slack water conditions. Continual observation of the Green Island discharge records may be helpful in determining the presence of steady-state flow conditions.

All sampling should be conducted during such periods when possible. Spatial surveys in the Hudson River Estuary are to be completed within two days.

5. The Hudson River Estuary is a transition tidal waterway. No data is presently available to assess the magnitude of the tidally induced dispersion process. Therefore, in addition to the foregoing, it is advised that an instantaneous dye release investigation be conducted to ascertain the significance of the dispersion mechanism on water quality.

B. Long-Term Temporal Program

1. Measurement at mid-channel and depth :
   a. Dissolved oxygen
   b Temperature
   c. Current velocity and direction
2. A continuous monitoring unit for determination of the foregoing criteria should be established in the Upper Hudson Estuary near Albany at the Dunn Memorial Bridge
3. Samples should be monitored continuously at one or two hour intervals.
4. In conjunction with the foregoing, it is suggested that BOD and COD data be collected on a periodic basis as practical.

Upper Hudson and Mohawk Rivers (including the Champlain Canal)

A. Spatial Sampling Program

1. Measurements at each sampling location at mid-channel and depth:

   a. Dissolved oxygen

   b. Biochemical oxygen demand (5-day)

   c Temperature

   d. Bacteriological examination

   e. pH

2 Measurement at each sampling station in the vicinity of and below major waste discharges at mid-channel and depth. This includes the Upper Hudson River below the Schroon River, the entire Mohawk River and Champlain Canal.

   a Ammonia nitrogen

   b Nitrite nitrogen

   c Nitrate nitrogen

   d. Total organic nitrogen

   e. Suspended solids

   f. Volatile suspended solids

3. Measurements at every fifth sampling location in the vicinity of and below major waste discharges.

   a. Chemical oxygen demand

   b. Benthal demand

c. Total phosphate

d. Total carbon

e. Warburg respirometer determinations (including supression of nitrification)

4. Based on the limited amount of previous data, it is advised that sampling stations be established at 5 mile intervals in the Upper Hudson and Mohawk Rivers and at 2 mile intervals in the Champlain Canal between Fort Edward and Whitehall. All major tributaries should be sampled as above at two stations within two miles of the main channel.

5. A minimum of two spatial surveys should be conducted on each component. It is advisable to perform sampling during periods of steady flow conditions, if possible. The surveys should be completed in as short a period of time as practical. Some preliminary work on vertical and lateral homogeneity is advised.

6. In those regions characterized by dam and lock installations, it is suggested that some work be conducted on reaeration as related to dam overflow.

7. The Champlain Canal should be studied simultaneously with the Upper Hudson River. Measurements should include an evaluation of water quality in the Hudson diversion at Glens Falls to the summit canal pool.

B. Short-Term Intensive Program

1. Continuous measurement at mid-channel and depth:

   a. Dissolved oxygen

   b Biochemical oxygen demand (light and dark bottle)

   c. Temperature

   d. Solar radiation

   The foregoing parameters should be measured at two hour intervals for a minimum duration of 48 hours but more desirably for ten days.

2. Daily measurement at mid-channel and depth:

   a. Chlorophyll extractables

   b. Total inorganic nitrogen

   c Total phosphate

3. The short-term intensive program should be conducted in any eutrophic area of suspect algal activity.

Lake Champlain

A. Spatial Sampling Program

1. Measurements at each sampling location and depth:

   a. Dissolved oxygen

   b. Biochemical oxygen demand (five day)

   c. Temperature

   d. pH

2. Measurements at each sampling location at surface, mid-depth and bottom:
   a. Ammonia nitrogen
   b. Nitrite nitrogen
   c. Nitrate nitrogen
   d. Total organic nitrogen
   e. Total phosphate
   f. Total carbon
   g. Chemical oxygen demand
   h. Bacteriological examination
3. It is recommended that sampling stations be established at 5 to 10 mile intervals along the course of Lake Champlain from Whitehall to the Canadian border. Each sampling station should be positioned to incorporate the centerpoint of a lateral extent not to exceed one mile. In those areas where the lateral width of Lake Champlain is greater than a mile, additional stations should be established, each incorporating a lateral mile or less.
4. At least ten equidistant depth samples are recommended for those measurements to be taken at every station and depth in areas greater than 50 ft. In the shallower regions, surface, mid-depth and bottom samples are sufficient. Representative measurement of bottom deposits are appropriate throughout the study area.

5. A complete water balance should be determined for Lake Champlain. Surface fresh water runoff, ground water inflow, rainfall, evaporation, transpiration and artificial fresh water sources and sinks require evaluation. Characteristic currents should be determined considering wind forces as a possible factor.

6. A minimum of two spatial surveys should be conducted on the lake: one during mid-summer when stratification is likely to be severe, and an additional investigation during the fall overturn. Periodic temperature-depth determinations will indicate the overturn period. The recommended sampling program is not intended as fully comprehensive but will be of value in assessing present conditions and required future investigations.

7. Localized pollutional conditions in littoral shoreline areas may suggest some sampling of a smaller scale. For major waste discharges in the Champlain region, it is recomended that radial surveys be conducted to chart the area of influence in lake waters. Dissolved oxygen, BOD, and coliform densities measured radially from outfall locations may be quantitatively analyzed and related to discharge loadings. Such data will be helpful in assessing localized water quality conditions resulting from future waste discharges.

B. Long Term Temporal Program.

1. Measurements at three equidistant depths:

   a. Dissolved oxygen

   b. Temperature

   c. pH

   d. Current velocity and direction

2. Samples should be monitored continuously on a one or two hour interval.

3. The practicability of locating a continuous monitoring unit in mid-lake at or near several existing buoys should be evaluated.

TABLE 1

NEW YORK CITY DEPARTMENT OF PUBLIC WORKS

SAMPLING STATIONS

Station	Location
Lower East River	
E-1	Pier 10
E-2	23rd Street
E-3	42nd Street
E-4	Hell Gate
Upper East River	
E-5	Baretto Point
E-6	Flushing Bay
E-7	Whitestone
E-8	Throgg's Neck
Long Island Sound	
E-9	Stepping Stones
E-10	Hart Island
Harlem River	
H-1	Spuyten Duyvil
H-2	Morris Heights
H-3	155th Street
H-4	Willis Avenue
H-5	106th Street
Jamaica Bay	
J-1	Rockaway Inlet
J-2	Mill Basin
J-3	Canarsie
J-5	L.I.R.R. Trestle
J-7	Bergen Basin

TABLE 1 (continued)

Station	Location
Kill Van Kull	
K-1	B. & O. Coal Dock
Newark Bay	
K-2	Shooters Island
Arthur Kill	
K-3	B. & O. R.R. Bridge
K-4	Fresh Kills
K-5	Tottenville
Lower New York Bay	
K-6	Orchard Light
Hudson River	
N-1	Mt. St. Vincent
N-2	Spuyten Duyvil
N-3	155th Street
N-4	42nd Street
N-5	Pier A - The Battery
Upper New York Bay	
N-6	Bellbuoy 1-G
N-7	Robbin's Reef
The Narrows	
N-8	The Narrows
Atlantic Ocean	
N-9	Steeplechase, Coney Island
N-16	SLFW-Gong
Rockaway Inlet	
N-9A	Coney Island Outfall

TABLE 2

RECOMMENDED SAMPLING STATION LOCATIONS

FOR THE UPPER HUDSON ESTUARY

Station	Miles Below Troy Lock	Approximate Position
1	0.2	Near Buoy "83" at Troy
2	1.8	Below Congress Street Bridge at Troy
3	4.0	Under power cable crossing at South Troy
4	6.0	Opposite Light "72"
5	8.4	Under Dunn Memorial Bridge at Albany
5a	9.1	Opposite Albany sewage treatment plant outfall
5b	9.8	Opposite Shed No. 3 at Port of Albany
6	10.4	Opposite Light "69"
7	13.3	Opposite Light "60"
8	15.9	Near Buoy "55" at Castleton
9	20.2	Near Light "45" at Coeymans
10	24.2	Opposite Buoy "35"
11	29.0	Below Light "17" at Coxsackie
12	31.8	Below Buoy "4" at Fourmile Point
13	36.8	Under power cables below Hudson
14	41.9	Above Light "52"
15	50.5	Above Buoy "32" at Saugerties

Note: These stations were established for a sampling program sponsored by the New York State Department of Health during 1964. The buoy and light numbers refer to the U.S.C.G.S. sounding charts of the area.

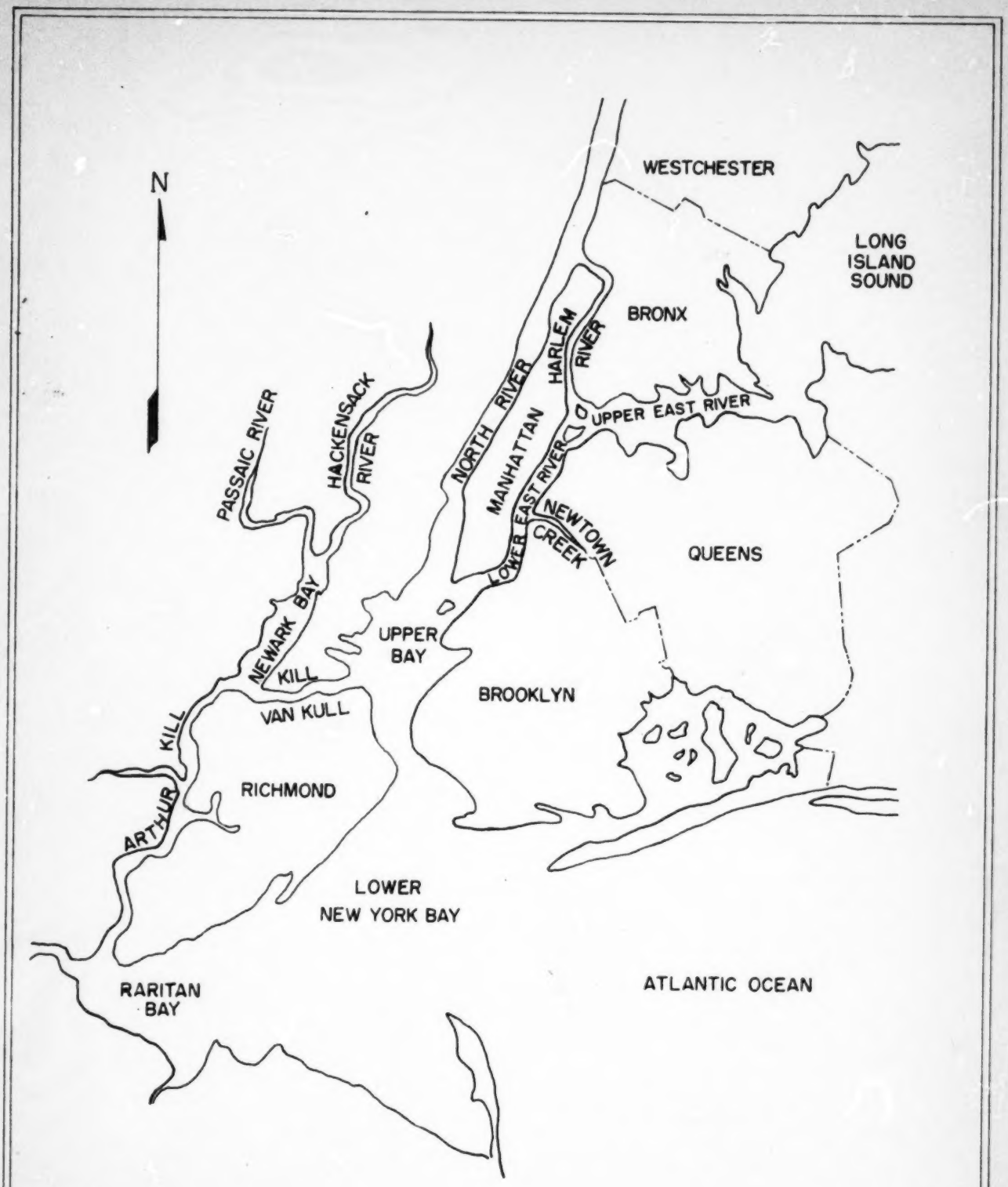


FIGURE 1

LOCATION MAP OF METROPOLITAN NEW YORK HARBOR COMPLEX

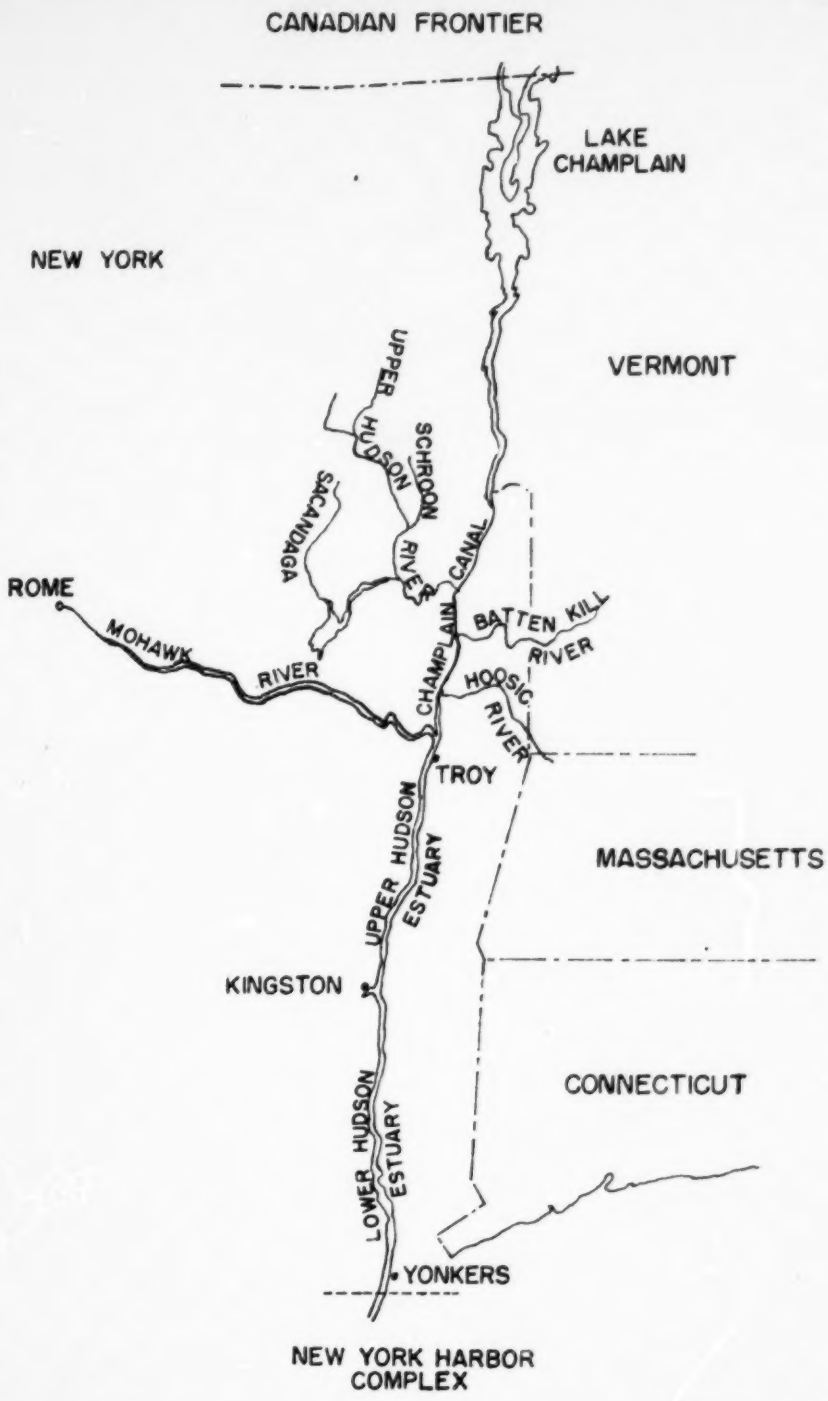
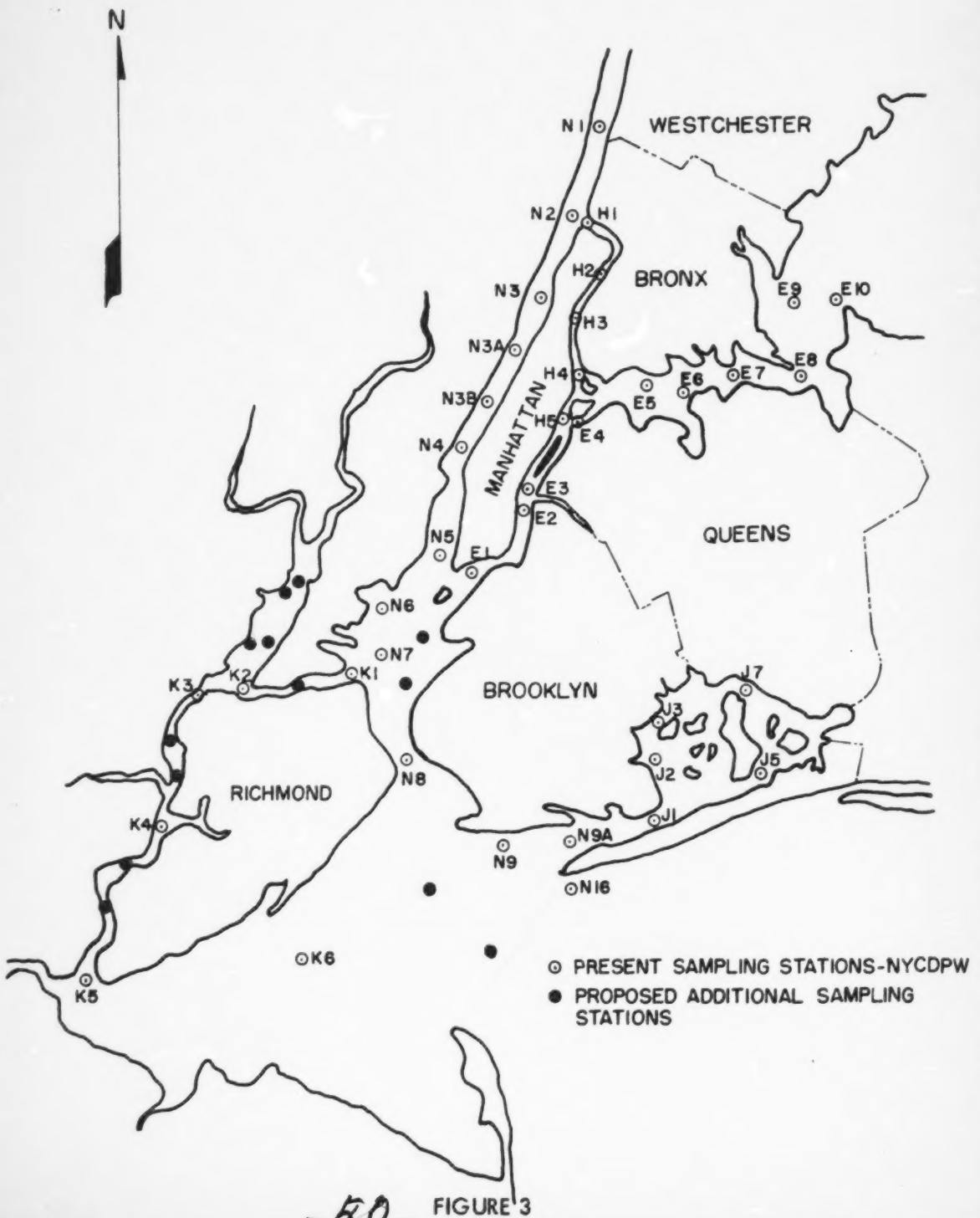


FIGURE 2

LOCATION MAP OF HUDSON RIVER, MOHAWK RIVER AND LAKE CHAMPLAIN



-50- FIGURE 3

PROPOSED SAMPLING STATIONS FOR METROPOLITAN NEW YORK HARBOR COMPLEX